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SCI IDENTIFICATION (SCIDNT) PROGRAM
USER'S GUIDE

SYSTEMS CONTROL, INC. (Vt)
1801 Page Mill Road
Palo Alto, California 94304

NASA Contract NAS1-14549
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Langley Research Center
Hampton, Virginia 23665

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UTTL: Development of advanced techniques for rotorcraft state estimation and parameter identification
UNCLASSIFIED JULY 19, 1976 / OCTOBER 15, 1978 A/266
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MAJS: /*AERODYNAMIC STABILITY/*ALGORITHMS/*CONTROL STABILITY/*CONTROLLABILITY/*DATA PROCESSING/*DATA REDUCTION/*FLIGHT CHARACTERISTICS/*FLIGHT CONTROL/*FLIGHT TESTS/*HELICOPTER PERFORMANCE/*HELICOPTERS/*POSTFLIGHT ANALYSIS/*PREDICTION ANALYSIS TECHNIQUES/*STABILITY DERIVATIVES

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79A18156* ISSUE 5 PAGE 758 CATEGORY 8 RPT#: AHS 78-30 CNT#: NAS1-14549 78/00/00 23 PAGES UNCLASSIFIED DOCUMENT
UTTL: Rotorcraft system identification techniques for handling qualities and stability and control evaluation
AUTH: A/HALL, W. E., JR.; B/GUPTA, N. K.; C/HANSEN, R. S. PAA: C/(Systems Control, Inc., Palo Alto, Calif.)
CORP: Systems Control, Inc., Palo Alto, Calif.
In: American Helicopter Society, Annual National Forum, 34th, Washington, D.C., May 15-17, 1978, Proceedings. (A79-18126 05-01) Washington, D.C., American Helicopter Society, 1978. 23 p.
MAJS: /*AIRCRAFT STABILITY/*COMPUTER AIDED DESIGN/*CONTROLLABILITY/*DESIGN ANALYSIS/*HELICOPTER DESIGN/*ROTARY WING AIRCRAFT
MINS: / ALGORITHMS/ DATA PROCESSING/ KALMAN FILTERS/ LEAST SQUARES METHOD/ MAXIMUM LIKELIHOOD ESTIMATES/ ONBOARD EQUIPMENT
ABA: (Author)
ABS: An integrated approach to rotorcraft system identification is described. This approach consists of sequential application of (1) data filtering to estimate states of the system and sensor errors, (2) model structure estimation to isolate significant model effects, and (3) parameter identification to quantify the coefficient of the model. An input design algorithm is described which can be used to design control inputs which maximize parameter estimation accuracy. Details of each aspect of the
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rotorcraft identification approach are given. Examples of both simulated and actual flight data processing are given to illustrate each phase of processing. The procedure is shown to provide means of calibrating sensor errors in flight data, quantifying high order state variable models from the flight data, and consequently computing related stability and control design models.

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81N22726*#   ISSUE 13   PAGE 1811   CATEGORY 61   RPT#: NASA-CR-159085
CNT#: NAS1-14549   79/11/00   54 PAGES   UNCLASSIFIED DOCUMENT

UTTL: INDES User's guide multistep input design with nonlinear rotorcraft modeling

CORP: Systems Control, Inc., Palo Alto, Calif.   AVAIL.NTIS   SAP: HC A04/MF A01

Sponsored in part by Army

MAJS: /*COMPUTER PROGRAMS/*INPUT/*NONLINEAR SYSTEMS/*ROTARY WING AIRCRAFT

MINS: / AERODYNAMIC CHARACTERISTICS/ ALGORITHMS/ COMPUTER PROGRAMMING/ DATA PROCESSING/ USER MANUALS (COMPUTER PROGRAMS)

ABA: M.G.

ABS: The INDES computer program, a multistep input design program used as part of a data processing technique for rotorcraft systems identification, is described. Flight test inputs base on INDES improve the accuracy of parameter estimates. The input design algorithm, program input, and program output are presented.

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81N22725*#   ISSUE 13   PAGE 1811   CATEGORY 61   RPT#: NASA-CR-159084
CNT#: NAS1-14549   79/11/00   29 PAGES   UNCLASSIFIED DOCUMENT

UTTL: SCI model structure determination program (OSR) user's guide --- optimal subset regression

CORP: Systems Control, Inc., Palo Alto, Calif.   AVAIL.NTIS   SAP: HC A03/MF A01

MAJS: /*COMPUTER PROGRAMS/*MATHEMATICAL MODELS/*REGRESSION ANALYSIS/*ROTARY WING AIRCRAFT

MINS: / AERODYNAMIC CHARACTERISTICS/ AERODYNAMIC COEFFICIENTS/ ALGORITHMS/ CORRELATION/ DATA PROCESSING/ INDEPENDENT VARIABLES/ INPUT/ OUTPUT

ABA: M.G.

ABS: The computer program, OSR (Optimal Subset Regression) which estimates models for rotorcraft body and rotor force and moment coefficients is described. The technique used is based on the subset regression algorithm. Given time histories of aerodynamic coefficients, aerodynamic variables, and control inputs, the program computes correlation between various time histories. The model structure determination is based on these correlations. Inputs and outputs of the program are given.

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81N22724*# ISSUE 13 PAGE 1811 CATEGORY 61 RPT#: NASA-CR-159083
CNT#: NAS1-14549 79/11/00 121 PAGES UNCLASSIFIED DOCUMENT

UTTL: NLSCIDNT user's guide maximum likehood parameter identification computer program with nonlinear rotorcraft model

CORP: Systems Control, Inc., Palo Alto, Calif. AVAIL.NTIS SAP: HC A06/MF A01

MAJS: /*COMPUTER PROGRAMS/*MAXIMUM LIKELIHOOD ESTIMATES/*NONLINEAR SYSTEMS/*ROTARY WING AIRCRAFT

MINS: / AERODYNAMIC COEFFICIENTS/ AERODYNAMIC STABILITY/ ALGORITHMS/ COMPUTER PROGRAMMING/ FLIGHT CONTROL/ OPTIMIZATION/ USER MANUALS (COMPUTER PROGRAMS)

ABA: M.G.

ABS: A nonlinear, maximum likelihood, parameter identification computer program (NLSCIDNT) is described which evaluates rotorcraft stability and control coefficients from flight test data. The optimal estimates of the parameters (stability and control coefficients) are determined (identified) by minimizing the negative log likelihood cost function. The minimization technique is the Levenberg-Marquardt method, which behaves like the steepest descent method when it is far from the minimum and behaves like the modified Newton-Raphson method when it is nearer the minimum. Twenty-one states and 40 measurement variables are modeled, and any subset may be selected. States which are not integrated may be fixed

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at an input value, or time history data may be substituted for the state in the equations of motion. Any aerodynamic coefficient may be expressed as a nonlinear polynomial function of selected 'expansion variables'.

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81N22723*# ISSUE 13 PAGE 1811 CATEGORY 61 RPT#: NASA-CR-159082
CNT#: NAS1-14549 79/11/00 50 PAGES UNCLASSIFIED DOCUMENT

UTTL: SCI Identification (SCIDNT) program user's guide --- maximum likelihood method for linear rotorcraft models

CORP: Systems Control, Inc., Palo Alto, Calif. AVAIL.NTIS SAP: HC A03/MF A01

MAJS: /*COMPUTER PROGRAMS/*LINEAR SYSTEMS/*MAXIMUM LIKELIHOOD ESTIMATES/*ROTARY WING AIRCRAFT

MINS: / AERODYNAMIC COEFFICIENTS/ AERODYNAMIC STABILITY/ ALGORITHMS/ COMPUTER PROGRAMMING/ FLIGHT CONTROL/ OPTIMIZATION/ USER MANUALS (COMPUTER PROGRAMS)

ABA: M.G.

ABS: The computer program Linear SCIDNT which evaluates rotorcraft stability and control coefficients from flight or wind tunnel test data is described. It implements the maximum likelihood method to maximize the likelihood function of the parameters based on measured input/output time histories. Linear SCIDNT may be applied to systems modeled by linear constant-coefficient differential equations. This restriction in scope allows the application of several analytical results which simplify the computation and improve its efficiency over the general nonlinear case.

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81N22722*# ISSUE 13 PAGE 1811 CATEGORY 61 RPT#: NASA-CR-159081
CNT#: NAS1-14549 79/11/00 69 PAGES UNCLASSIFIED DOCUMENT
UTTL: DEKFIS user's guide: Discrete Extended Kalman Filter/Smoother program for aircraft and rotorcraft data consistency
CORP: Systems Control, Inc., Palo Alto, Calif. AVAIL.NTIS SAP: HC A04/MF A01
MAJS: /*COMPUTER PROGRAMS/*DATA SMOOTHING/*FIXED WINGS/*KALMAN FILTERS/*ROTARY WING AIRCRAFT
MINS: / ALGORITHMS/ COMPUTER PROGRAMMING/ ERROR CORRECTING DEVICES/ ESTIMATING/ INSTRUMENT ERRORS/ LINEARIZATION/ NONLINEAR EQUATIONS/ USER MANUALS (COMPUTER PROGRAMS)
ABA: M.G.
ABS: The computer program DEKFIS (discrete extended Kalman filter/smoother), formulated for aircraft and helicopter state estimation and data consistency, is described. DEKFIS is set up to pre-process raw test data by removing biases, correcting scale factor errors and providing consistency with the aircraft inertial kinematic equations. The program implements an extended Kalman filter/smoother using the Friedland-Duffy formulation.

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81N19098*# ISSUE 10 PAGE 1302 CATEGORY 5 RPT#: NASA-CR-159297
CNT#: NAS1-14549 80/11/00 265 PAGES UNCLASSIFIED DOCUMENT

UTTL: Development of advanced techniques for rotorcraft state estimation and parameter identification

AUTH: A/HALL, W. E., JR.; B/BOHN, J. G.; C/VINCENT, J. H.

CORP: Systems Control, Inc., Palo Alto, Calif. AVAIL.NTIS SAP: HC A12/MF A01

MAJS: /*AERODYNAMIC CHARACTERISTICS/*MATHEMATICAL MODELS/*PARAMETER IDENTIFICATION/*ROTARY WING AIRCRAFT

MINS: / AEROELASTICITY/ DEGREES OF FREEDOM/ HELICOPTER DESIGN/ KALMAN FILTERS/ MAXIMUM LIKELIHOOD ESTIMATES/ ROTOR AERODYNAMICS

ABA: A.R.H.

ABS: An integrated methodology for rotorcraft system identification consists of rotorcraft mathematical modeling, three distinct data processing steps, and a technique for designing inputs to improve the identifiability of the data. These elements are as follows: (1) a Kalman filter smoother algorithm which estimates states and sensor errors from error corrupted data. Gust time histories and statistics may also be estimated; (2) a model structure estimation algorithm for isolating a model which adequately explains the data; (3) a maximum likelihood algorithm for estimating the parameters and estimates for the variance of these estimates; and (4) an input design algorithm, based on a maximum

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likelihood approach, which provides inputs to improve the accuracy of parameter estimates. Each step is discussed with examples to both flight and simulated data cases.

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N81- 22723#

I. INTRODUCTION AND OVERVIEW

System identification technology has been used successfully for many vehicles. Because of their large number of degrees of freedom and complex aerodynamic interactions, the rotorcraft have always presented a special challenge to system identification methods. A completely integrated methodology has been developed under this NASA contract to solve this difficult problem. This methodology has also been translated into a user oriented series of computer programs. This volume provides basic guidelines for efficient and effective use of one of these computer programs.

Figure 1 shows a schematic flowchart of the overall data processing technique for rotorcraft. The first step in this procedure is state estimation and instrument calibration. This is implemented by the computer program DEKFIS (for Discrete Extended Kalman Filter and Smoother) which implements an extended Kalman filter/smoother using the Friedland-Duffy formulation. Instrument biases and scale factors are estimated at this stage together with any state which is not measured directly. The second step involves estimation of the mathematical model of various forces, moments and interchanges. This is implemented in OSR (Optimal Subset Regression) computer program which uses a regression technique. Accurate estimates of parameters are obtained in the final step. One of two computer programs is used for this purpose. SCIDNT implements the maximum likelihood method for linear systems and NLSCIDNT extends the method to nonlinear rotorcraft models.

The contract research effort which led to the results in this report was financially supported by the Structures Laboratory, USARTL (AVRADCOM), NASA Langley Research Center and NASA Ames Research Center.

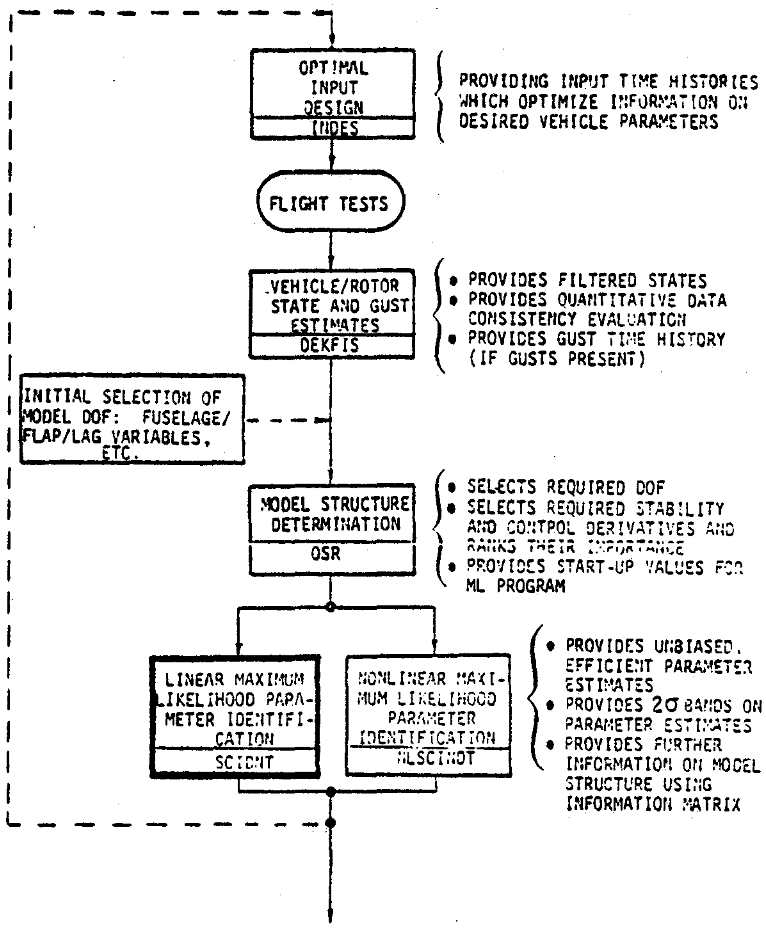

Figure 1 Integrated Rotorcraft System Identification Procedure

Accuracy of parameter estimates may be improved by using flight test inputs based on the input design program, INDES.

This user's manual describes the SCIDNT computer program. The details of the theory and the particular implementation used are given in the final report.*

---

* Hall, W.E., Gupta, N.K., Hansen, R. and Bohn, J., "State Estimation and Parameter Identification for Rotorcraft," Final Report on Contract NAS1-14549, May 1978.

II. BACKGROUND

The computer program Linear SCIDNT (from SCI maximum likelihood IDenTification for linear systems) evaluates rotorcraft stability and control coefficients from flight or wind tunnel test data. It implements the maximum likelihood method to maximize the likelihood function of the parameters based on measured input/output time histories. Linear SCIDNT may be applied to systems modeled by linear constant-coefficient differential equations. This restriction in scope allows the application of several analytical results which simplify the computation and improve its efficiency over the general non-linear case. The functions of Linear SCIDNT may be summarized as follows. For the linear system:

$$\frac{d}{dt} x(t) = F(\theta)x(t) + G(\theta)u(t) + \Gamma(\theta)w(t)$$

$$y(t_k) = H(\theta)x(t_k) + D(\theta)u(t_k) + v(t_k) \; ; \quad k=1,2,\ldots,N$$

where

$$E[w(t)w^T(\tau)] = Q(\theta)\;\delta(t-\tau)$$

$$E[v(t_k)v^T(t_\ell)] = R(\theta)\;\delta_{k\ell}$$

$$E[v(t)w^T(\tau)] = 0$$

θ = a vector of parameters to be identified

where $\delta(t-\tau)$ and $\delta_{k\ell}$ are Dirac delta functions. Linear SCIDNT estimates specified elements of the parameter vector θ.

The program has the following special features:

(1) The program is set up for rotorcraft models.

(2) The applicable model may be specified depending on the measured response (this includes rotor, body, rotor/body, coupled and uncoupled, longitudinal and lateral models). The set of measurements may also be selected depending on available instruments.

(3) The program estimates the standard deviations and confidence levels of all parameter estimates.

(4) Up to 120 parameters can be identified in one run.

(5) Multiple maneuvers can be processed in one run.

(6) The user can specify that any of the parameters are known constants or are to be identified.

(7) Extensive diagnostic printouts can be switched on to aid the user in setting up the input deck properly before making a complete run.

(8) The user has the option of producing time history records of actual and estimated measurements in the form of tabular printout, printer plots, or magnetic tape for off-line high resolution plotting.

III. PROGRAM STRUCTURE

This section gives a brief discussion of the major subroutines and functional blocks of Linear SCIDNT. Figure 3.1 shows the basic program structure.

The main routine, DRIVER, is responsible for setting up the problem for the optimization routine SMAIN, calling SMAIN and then performing output tasks such as printing and/or storing (for later plotting) control and actual vs. estimated time histories.

SMAIN, the optimization routine, uses the Levenberg-Marquardt search procedure to drive the identified parameters to values such that the likelihood function is maximized. As the parameters are stepped, information is printed out describing the progress of each iteration.

UPDATE is called by SMAIN to calculate the likelihood function, its gradient, with respect to the parameters and the information matrix (an approximation to the Hessian of the likelihood function with respect to the parameters). The cost and gradient are derived from propagation of the measurement and measurement sensitivity (with respect to each parameter) equations, performed by UPDATE, using the transition matrix technique. UPDATE also contains special code for the case when the model is assumed to have process noise excitation.

In addition to the functional blocks described above, numerous other small routines are called to perform utility tasks, such as specially formatted printout, pointer manipulation, and matrix algebra.

DIMENSION ARRAYS

↓

READ TITLE, PROBLEM SIZE,
ALGORITHM PARAMETERS, ETC.

↓

READ PARAMETER STARTING
VALUES AND SET UP SYSTEM
MATRICES

↓

PRINT OUT INITIAL SYSTEM
MATRICES, OPTIONALLY
EIGENVALUES

↓

READ AND OPTIONALLY
PRINT OUT u AND y TIME
HISTORIES

↓

CONDUCT PARAMETER SEARCH → { ITERATE TO MINIMUM COST (1,NITER) OR CONVERGENCE → { PUT NEW PARAMETERS INTO SYSTEM MODEL; FIND COST, GRADIENT, INFORMATION MATRIX → { PROPAGATE MEASUREMENT AND MEASUREMENT SENSITIVITY EQUATIONS. GENERATE APPROX. TO HESSIAN, I.E., INFORMATION MATRIX. }; COMPUTE STEP; UPDATE PARAMETERS BY STEP } }

↓

PRINT OUT FINAL SYSTEM
MATRICES, OPTIONALLY
EIGENVALUES

↓

PRINT OUT AND/OR PLOT
ESTIMATED VS. ACTUAL
MEASUREMENT AND CONTROL
TIME HISTORIES

Figure 3.1 General Flowchart of SCIDNT

IV. INPUTS TO THE PROGRAM

Linear SCIDNT requires two classes of input. The first type, which will be referred to as "card-input" defines the model, its size (number of states, etc.), and its parameters, including indicators as to which ones are to be identified. Other quantities read include controls over the optimization routine, printout flags, and plot control flags. Card-input is read from unit 5.

The second type of input referred to as "time-history input" consists of tabular values of the measurement and control time histories. SCIDNT calls a subroutine INREAD once before beginning the identification algorithm. Subroutine INREAD reads the values of the measurements y and controls u for the entire time period of the experiment. This is because in general, INREAD must read data in many different formats for various types of simulation or flight test data.

4.1 CARD INPUT

4.1.1 General

Card-input to Linear SCIDNT consists of three different groups of cards. The first group, consisting of only one card, specifies a 76-character title to be printed at the top of every page of output. This serves to identify the run and/or the data which is specified as input.

The second group, a NAMELIST data deck called INPUT, specifies the problem size (number of states, number of measurements, etc.), optimization algorithm controls, and program output controls.

The third group of cards specifies the numerical values of the parameters in the model and flags the ones to be identified. Parameters not flagged are assumed to be fixed and known. Also indicated on these cards are parameter labels, parameter initial values, and upper and lower bounds for identified parameters. The bounds are useful for parameters such as sines or cosines, whose magnitude must not exceed 1.

A detailed description of card input is seen in Table 4.1. The NAMELIST cards are punched according to usual NAMELIST conventions, such as free format between columns 2 and 72, order independence, etc. See the applicable FORTRAN manual for more details. A sample input deck is shown in Figure 4.1.

4.1.2 Detailed Explanation of Selected Card-Inputs

K1MAX

K1MAX specifies the maximum number of successful iterations that the optimization algorithm will perform before returning to the main program. Each successful iteration represents a step toward the maximum of the likelihood function (equivalently, the minimum of the negative log of the likelihood function, which is the actual cost function used). If convergence is achieved in less than K1MAX iterations, then the final values of the parameters will reflect the last step calculated. If convergence is not achieved in K1MAX iterations, the parameters will have the values before the last step was calculated. This feature allows the initial and final parameter values to be equal when K1MAX is input as 0. In this fashion, time history plots of the system with the initial values of the parameters can be generated, and the first step calculated on a low-cost checkout run. An even lower-cost checkout run can be made by setting K1MAX = -1, which is the same as setting K1MAX = 0, but without a calculation of the first step.

Table 4.1
Input Card Formats

CARD GROUP	COLUMNS	FORMAT	VARIABLE NAME AND DESCRIPTION
Title	1-76	19A4	Run and/or Program identification.
INPUT Namelist	2-72	Free	First card must begin with $INPUT followed by $END. Intervening cards set values for the following variables (defaults in parentheses):
		Integer	NS = number of states (22)
		Integer	NP = number of measurements (25)
		Integer	NQ = number of controls (8)
		Integer	NN = number of time points to be read by INREAD from data file (21). Can be negated to trigger data printout by INREAD.
		Integer	K1MAX = maximum number of iterations (6). See notes.
		Integer	K2MAX = maximum number of cost function increases per iteration (4). See 4.1.2. (step cuts)
		Integer	MCYCLE = number of parameters identified per iteration (min(# parameters id'd,12)). Must be less than or equal to total number of parameters identified. See 4.1.2.
		Integer	NG = number of process noise sources (6). If equal to zero, output error option is assumed. See 4.1.2.
		Integer	IRCMP = 0, R-matrix not updated. IRCMP > 0, R-matrix updated every IRCMP iterations. See 4.1.2.

Table 4.1 (Continued)

CARD GROUP	COLUMNS	FORMAT	VARIABLE NAME AND DESCRIPTION
INPUT Namelist (Cont'd)	2-72	Free	
		Integer	IPRT = 0, No diagnostic printout IPRT = 1, State and measurement debugging printout IPRT = 2, State and measurement sensitivity debugging printout IPRT = 4, Information matrix debugging printout. Default = 0. Note: These values may be summed to obtain combined printouts. Also, the sum may be negated to obtain time histories associated with each level of printout. See 4.1.2.
		Real	DELTA = Sample time increment of input measurement and control time histories (.05 seconds)
		Logical	EIGF = Calculate and print out F-matrix eigenvalues before and after optimization procedure (.FALSE.)
		Logical	PRTTB = Print out tabular time history of controls and actual vs. estimated measurements. (.FALSE.)
		Logical	PRTPL = Produce printer plots of controls and actual vs. estimated measurements (.FALSE.)
		Logical	TAPEPL = Produce mass storage file of controls and actual vs. estimated measurements. These time histories are written on unit 2 and can be used as input for off-line plotting. (.FALSE.)
		Integer	NREC = Number of maneuvers in data record (1)
		Integer Array	IREC = The Ith maneuver starts at the IREC(I)th data point (1)

Table 4.1 (Continued)

CARD GROUP	COLUMNS	FORMAT	VARIABLE NAME AND DESCRIPTION
INPUT Namelist (Cont'd)	2-72	Free	
		Integer	MAXP = maximum number of parameters (computed from other inputs)
		Integer	NTERMS = # of terms in transition matrix series evaluation (20)
		Integer	IPRTSM = 0 prints inputs for FMARQ, PMARQ, NTERMS, odd turns on level 1 print (0)
		Logical	USERLAB = .TRUE. to read user supplied labels for plots (.FALSE.)
		Real	FMARQ = initial Marquard search parameter (30.)
		Real	PMARQ = factor for increase or decrease of Marquard parameter (1.)
		Real	DEFBDU = upper bound default on P (10^6)
		Real	DEFBDL = lower bound default on P (-10^6)
		Real	STEPMN > $\|STEP\|^2$ defines convergence (.001)
		Real	RELERR > |relative change in likelihood function| defines convergence (10^{-6})
USER LABELS	1	A1	CHAR = Y for measurement label = U for control label
	3-4	I2	INDEX = which measurement or control
	11-50	4A10	ALABEL (I), I = 1,4 label

Table 4.1 (Continued)

CARD GROUP	COLUMNS	FORMAT	VARIABLE NAME AND DESCRIPTION
Parameter	1	A1	J2 = blank: this parameter is to be held fixed throughout the optimization J2 = non-blank: this parameter is to be identified
	2	A1	ECHK = non-blank: terminator card for the parameter group
	6-25	4I5	(IPX(I),I=1,4), pointers to positions in which this parameter appears in linear system (see 4.1.2)
	26-35	A10	PLAB: Parameter name.
	36-50	E15.7	PVAL: If this parameter is identified, P is its starting value. If it is not identified, P is its known value. (Default = 0.) Fixed parameters of value zero need not be specified in the parameter card group.
	51-65	E15.7	PLJ1: Lower bound of this parameter, if identified. Default = -1.0E+6
	66-80	E15.7	PUJ1: Upper bound of this parameter, if identified. Default = 1.0E+6
			See 4.1.2 for more detailed description of parameter card group

```
COLUMN
 1

 ROTORCRAFT SCIDNT TEST CASE      Title Card
 $INPUT
 NS=14.
 NP=14.
 NQ=4.
 NG=0.
 RMARQ=30., PMAPQ=1.,             $INPUT Namelist
 K1MAX = 10.
 K2MAX=20.
 NN=501.
 DELTA=.01.
 TAPEPL=.TRUE.,
 EIGF=.TRUE.,
 PRTPL=.TRUE.,
 $END
*        1   253            XU           -.0048     PARAMETER SPECIFICATION
*        2   254            YU            .0156              CARDS
*        3   255            ZU           -.124
*        4   256            LU           -.0011
*        5   257            MU           -.0005
*        6   258            NU           -.0016
        10                  BOU           .0294
        12                  BAU           .0891
        14                  BBU          -.0644
*       15   267            XV            .00042
*       16   268            YV           -.0567
*       17   269            ZV           -.0071
*       18   270            LV           -.0158
*       19   271            MV            .0023
*       20   272            NV            .0081
        24                  BOV           .0005
        26                  BAV          -.0707
        28                  BBV          -0.0506
*       29   281            XW            .0942
*       30   282            YW            .00216
*       31   283            ZW           -.744
*       32   284            LW           -.0099
*       33   285            MW            .0016
*       34   286            NW           -.0002
        38                  BOW           .432
        40                  BAW           .0379
        42                  BBW          -.0945
*       43   295            XP           -.126
        44                  YP-VSAL0      6.63
*       45   297            ZP           -6.12
*       46   298            LP           -.172
*       47   299            MP           -.0055
*       48   300            NP            .111
        49   135   165   195 ONE          1.
        52                  BOP           .495
        54                  BAP          -8.46
        56                  BBP          -15.2
        57                  XQ-VSTH0     -9.47
*       58   310            YQ           -.659
        59                  ZQ+VCTH0      193.
*       60   312            LQ            .017
*       61   313            MQ           -5.0
*       62   314            NQ            .0594
        63                  SPHOTTH0      0.
        64                  CPH0          1.
        66                  BOQ          -3.97
        68                  BAQ          -16.8
```

ID Flag | Parameter Location Pointers | Parameter Name | Startup Values

Figure 4.1 Sample Input Data

PARAMETER SPECIFICATION CARDS (CONT.)

	70		RHO	12.1
•	71	323	XR	.485
	72		YR-VCAL0	-167.0
•	73	325	ZR	4.4
•	74	326	LR	.443
•	75	327	MR	.0045
•	76	328	NR	-.726
	77		CPHOTTHO	.0447
	78		-SPHO	0.
	80		B0R	-3.96
	82		BAR	.156
	84		BBR	-.72
	86		GCPHOCTHO	32.2
	87		-PSPHOCTHO	0.
	99		-GCTHO	-32.2
	100		-GSPHOSTHO	0.
	101		-GCPHOSTHO	-1.44
	113	365	XA0	25.1
	114	366	YA0	-10.1
	115	367	ZA0	-218.
	116	368	LA0	-.52
	117	369	MA0	-.064
	118	370	NA0	-1.4
•	122		B0A0	-165.
•	124		BAA0	89.5
•	126		BBA0	-8.31
	127	379	XA0DOT	.0416
	128	380	YA0DOT	-.376
•	129	381	ZA0DOT	.799
	130	382	LA0DOT	-.01
	131	383	MA0DOT	-.0421
	132	384	NA0DOT	-.0152
•	136		B0A0DOT	-13.7
•	138		BAA0DOT	3.32
•	140		BBA0DOT	1.56
	141	393	XA1	-24.
	142	394	YA1	4.32
	143	395	ZA1	-11.1
	144	396	LA1	-4.56
	145	397	MA1	3.84
	146	398	NA1	-.83
•	150		B0A1	19.0
•	152		BAA1	-47.
•	154		BBA1	154.
	155	407	XA1DOT	-2.51
	156	408	YA1DOT	-.21
	157	409	ZA1DOT	3.78
	158	410	LA1DOT	-.472
•	159	411	MA1DOT	.3
	160	412	NA1DOT	-.0532
•	164		B0A1DOT	.949
•	166		BAA1DOT	-19.4
•	168		BBA1DOT	22.8
	169	421	XB1	-1.91
	170	422	YB1	25.8
	171	423	ZB1	11.7
	172	424	LB1	17.8
	173	425	MB1	1.0
	174	426	NB1	1.84
•	178		B0B1	-16.8
•	180		BAB1	-161.
•	182		BBB1	-48.7
	183	435	XB1DOT	-.49
	184	436	YB1DOT	.923
	185	437	ZB1DOT	-4.49
	186	438	LB1DOT	1.07

Figure 4.1 (Continued)

```
     187  439             MHIDOT     .104    PARAMETER
     188  440             NHIDOT     .08     SPECIFICATION
*    192                  B0B1DOT    -.59    CARDS (CONT)
*    194                  BAB1DOT    -23.7
*    196                  BBB1DOT    -17.6
     296                  YP         -.91
     309                  XQ         -2.42
*    197  449             XTHIS      -4.92
*    198  450             YTHIS       12.0
*    199  451             ZTHIS       124.
*    200  452             LTHIS       .913
*    201  453             MTHIS      -.352
*    202  454             NTHIS      -.0905
*    206                  B0THIS     -64.2
*    208                  BATHIS     -117.
     210                  BBTHIS      163.
     211  463             XTHIC      -4.92
     212  464             YTHIC       11.9
     213  465             ZTHIC       17.1
     214  466             LTHIC       3.33
     215  467             MTHIC      -.0795
     216  468             NTHIC      -.543
     220                  B0THIC      9.82
     222                  BATHIC      163.
     224                  BBTHIC      110.
     225  477             XDLTR      -.48
     226  478             YDLTR       6.67
     227  479             ZDLTR       .534
     228  480             LDLTR       3.85
     229  481             MDLTR       .0078
     230  482             NDLTR      -5.17
     234                  B0DLTR     -1.94
     236                  BADLTR     -.53
     238                  BBDLTR      .29
     239  491             XTHO        26.5
     240  492             YTHO       -.708
     241  493             ZTHO       -269.
     242  494             LTHO       -3.45
     243  495             MTHO        .66
     244  496             NTHO        4.7
     248                  B0THO       231.
     250                  BATHO       30.7
     252                  BBTHO      -84.
     311                  ZQ          24.4
     324                  YR          1.61
     301  316  331  346   ONE         1.
     361  376  405  434   ONE         1.
     505                  QAX            1.25E-02
     520                  QAY            1.25E-02
     535                  QAZ            1.25E-02
     550                  QPDOT          1.53E-05
     565                  QQDOT          1.53E-05
     580                  QRDOT          1.53E-05
     595                  QP             3.79E-06
     610                  QQ             3.79E-06
     625                  QR             3.79E-06
     640                  QPHI           1.45E-07
     655                  QTHETA         1.45E-07
     670                  QA0            5.78E-07
     685                  QA1            5.78E-07
     700                  QB1            5.78E-07
**
```

Figure 4.1 (Continued)

K2MAX

Sometimes the calculated step of a given iteration is too large, causing the negative log likelihood function to increase. When this happens, the optimization algorithm cuts back the step until the cost decreases. K2MAX limits the number of times that this can occur in an iteration. The default value of 4 should be sufficient for most cases.

MCYCLE

Although every parameter can be moved during each iteration, significant savings of computer time can be realized if only a portion of the total number of identified parameters are stepped each iteration, especially if there are many (> 20) parameters to be identified. MCYCLE determines how many parameters are stepped at each iteration. If MCYCLE = 0, or is absent, then all the parameters are stepped at once each iteration, up to a maximum of 60. If MCYCLE > 0, then MCYCLE parameters are stepped. The identified parameters are grouped MCYCLE at a time in the order that they appear in the parameter cards. Different MCYCLE groupings can be achieved by rearranging the parameter cards. If the total number of identified parameters is not an even multiple of MCYCLE, the remainder of parameters in the last MCYCLE group are taken from the first group, and subsequent MCYCLE groups are changed accordingly. MCYCLE must be less than or equal to the number of identified parameters, and must never be greater than 60.

Note that this advanced computation technique was introduced into the computer program to save execution time while solving large order problems. The final estimates of parameters should be the same (within limits of numerical error and one standard deviation of parameter estimation error), irrespective of the value of MCYCLE. This technique has been used in the optimization of large static econometric models and is based on a similar technique proposed by Golub and Pereyra [1].

NG

Setting NG > 0 activates the process noise option of Linear SCIDNT, in which the linear model is assumed to be excited by random disturbances. If this option is used, parameters for Γ and Q matrices should appear in the parameter cards. Since the process noise case assumes that the estimated state is the output of a Kalman filter, which must be calculated, significant computational overhead is required for this option. However, improved accuracy of parameter estimates can be realized for data contaminated with process noise. If NG > 0, the input values of the R and Q matrices determine the dynamics of the state estimator.

If NG is set to 0, the output error option of the program is used. In this case, all errors between estimated and observed measurements are assumed to be due to measurement noise. No Γ or Q matrices are used, and the input R matrix is not used in the calculations, as measurement noise covariance is estimated from the data. Output error mode runs faster than process noise, and should be used when disturbances are known to have negligible effect on the data.

IRCMP

In the process noise option, the input value of the R-matrix is used to compute the Kalman filter gains. However, if the program has run for a few iterations, a better estimate of R can sometimes be obtained from the data and from new estimates of the process noise covariance. If IRCMP > 0, then the R-matrix used in the Kalman filter calculation is updated by the program every IRCMP iterations. If IRCMP = 0, R is held fixed at its input value. Every time R is updated, its new value is printed out.

In the output error option, IRCMP has no effect on the calculations. However, better estimates of R for future runs

can be obtained by setting IRCMP = 1, which will cause an estimate of R to be printed at each iteration.

IPRT

IPRT can be used to trigger several levels of diagnostic printout. Positive values of IPRT display matrices associated with each level of printout. (Level 4 is the same as Level 2, since there are no new matrices associated with the information matrix calculation.) Level numbers can be summed to obtain combined printouts. For example, IPRT = 3 causes a combined Level 1 and Level 2 printout, and IPRT = 7 includes all levels of printout. If the value of IPRT is negated, then time histories associated with each level are printed, as well as matrices. (IPRT = -4, -5, -6, or -7 will include a time history printout of the sensitivities used to compute each element of the information matrix).

Caution: Values of IPRT of magnitude greater than 1 will cause voluminous output. If such printouts are desired, it is best to set K1MAX = 0, and identify just a few parameters (1 or 2, if possible). If IPRT < 0, try to limit the number of data points to be 20 or fewer.

IPX Vector

IPX is read from a parameter card and determines the position in which the parameter appears in the system matrices. A parameter may appear in as many as four matrix elements, and the pointers to these elements are determined as follows. If the columns of the matrices (in the order F, G, H, D, R, Γ, Q) are stacked into one long vector, then the pointer to a given matrix element is equal to that element's position in the long vector. The four elements of IPX correspond to the four matrix elements in which a parameter can appear. Of the four fields on the parameter card for IPX elements, the leftmost

ones are used for non-zero values of IPX, i.e., unused IPX fields must appear on the right. The ranges of values for the pointers are as follows:

Elements In	Go From	To
F	1 (IF)	IF+NS*NS =(IG-1)
G	IG	IG+NS*NQ =(IH-1)
H	IH	IH+NP*NS =(ID-1)
D	ID	ID+NP*NQ =(ID-1)
R	IR	IR+NP*NQ =(IGAM-1)
Γ*	IGAM	IGAM+NS*NG =(IQ-1)
Q*	IQ	IQ+NG*NG

4.2 TIME HISTORY INPUT

Time history input is read by subroutine INREAD. Because measurement and control time histories can be retrieved from tape, cards, or disk in numerous formats, INREAD is left as a user-written routine. The INREAD used in the sample run is shown in Figure 4.2.

Subroutine INREAD

```
SUBROUTINE INREAD (NP,NQ,NN,DELTA)
COMMON/TLCM/T(1)
COMMON/ULCM/U(1)
COMMON/YLCM/Y(1)
LEVEL 2, T, U, Y
```

Inputs: NP = number of measurements
NQ = number of controls
NN = number of data points
DELTA = time history sample interval (seconds)

*Used only with process noise option

Outputs: T = array for storing the time of each data point

U = array for storing the control time history

Y = array for storing the measurement time history

NN = number of data points actually read from file

Notes: (1) The program uses the array T only for the plot outputs. The identification algorithm does not require T. The variable DELTA is passed to INREAD mainly for calculation of this array, and otherwise may be ignored (although a place must be held for it in the parameter list). This calculation can be done if the data file does not explicitly have on it the time for each data point.

(2) As noted under "outputs," NN may be reset by INREAD to reflect the actual number of data points read from the file. This must be done if, for example, an end-of-file is reached before the anticipated number of data points are read. If NN is reset, a message to that effect should be printed.

(3) INREAD should not reset the values of NP or NQ. DELTA may be reset, but if that occurs, a message to that effect should be printed, as an incorrect sample time can have disastrous effects on later computation.

(4) INREAD may perform any desired pre-processing of Y and U.

(5) It is recommended that INREAD print out the Y and U as arrays immediately after reading them to check the validity of the data, as shown in the example. DRIVER, which calls INREAD, has been coded so that a negative value of NN can be read from NAMELIST $INPUT, and then passed to INREAD to trigger this printout, should the user desire to incorporate it. If NN comes into INREAD as a negative value, it must be reset positive via the IABS function before returning to DRIVER.

(6) If the user should require additional card input in INREAD to control the processing of the input data, the cards can be placed immediately after the parameter description group of cards. Card input is on unit 5.

(7) The arrays T, U, and Y are in LCM. Note that the INREAD declaratives specify only the starting addresses of these arrays and not their dimensions. Therefore, when these arrays are read they must be considered singly dimensioned, and the variables NP, NQ, and NN must be used to calculate the proper subscript for these arrays. T is a vector, U is assumed to have NQ rows and NN columns, and Y is assumed to have NP rows and NN columns.

V. OUTPUTS OF THE PROGRAM

Four forms of output can be obtained from Linear SCIDNT. They are:

(1) Tabular printout showing the progress of the parameter estimation process.

(2) Tabular printout of time histories of controls, measurements, and measurcment estimates using the final values of identified parameters, (PRTTB = .TRUE.)

(3) Printer plots of control, measurement, and measurement estimate time histories, (PRTPL = .TRUE.)

(4) Control, measurement, and estimated measurement time history data stored on mass storage to generate off-line plots, (TAPEPL = .TRUE.)

The first type of output is always produced. The last three are optional and may be independently selected by the user.

5.1 TABULAR PRINTOUT OF ITERATION PROGRESS

Figure 5.1 is an example printout of a SCIDNT run using the card input shown in Figure 4.1. Explanations of the results are noted on the printout.

5.2 PRINTER PLOTS

Figures 5.2 and 5.3 show typical printer plots of measurement and control time histories. Actual and estimated time histories for each measurement are plotted on the same axis so that closeness of fit can be visually evaluated.

5.3 TIME HISTORY ON MASS STORAGE

This option is provided to put measurement and control time history data on a mass storage file, primarily for the purpose of producing off-line plots analogous to the printer plots. Data is written to the device (logical unit 2) in unformatted records as follows:

Record	Data
1	NS, NQ, NP, NN NS = number of states NQ = number of controls NP = number of measurements NN = number of data points per variable
2 through NN+1	T(J),(U(K,J),K=1,NQ),(Y(K,J),K=1,NP), (YHAT(K,J),K=1,NP) T(J) = time for Jth data point U(K,J) = Kth control at Jth data point Y(K,J) = Kth actual measurement at Jth data point YHAT(K,J) = Kth estimated measurement at Jth data point
NN+2	End-of-file mark

[illegible] NAS LIMIT EXCEEDED

60 PARAMETERS TO BE IDENTIFIED . . . [illegible]
16 STATES . . . . [illegible]
14 MEASUREMENTS . . . . [illegible]
4 CONTROLS . . . . [illegible]
0 PROCESS NOISE SOURCES . . . . [illegible]
12 CYCLED PARAMETERS . . . . [illegible]

THE SAMPLE TIME INTERVAL IS 1.000E-02

MAXIMUM NUMBER OF ITERATIONS IS 10.
MAXIMUM NUMBER OF STEP CUTS IS 20.

INITIAL MARQUARDT PARAMETER = 1.00000E+00
MARQUARDT PARAMETER FACTOR = 3.00000E+01

TRANSITION MATRIX SERIES EVALUATION CARRIED OUT TO 20 TERMS.

INITIAL PARAMETER VALUES

PARAMETER NAME	PARAMETER INDEX ACCORDING TO MATRIX STACKING	INDEX OF IDENTIFIED PARAMETERS	PARAM VALUES	LOWER BOUND	UPPER BOUND
XU	1	1	-3.60000E-03	-1.00000E+06	1.00000E+06
YU	2	2	1.95000E-02	-1.00000E+06	1.00000E+06
ZU	3	3	-9.20000E-02	-1.00000E+06	1.00000E+06
LU	4	4	-1.37500E-03	-1.00000E+06	1.00000E+06
MU	5	5	-3.75000E-04	-1.00000E+06	1.00000E+06
NU	6	6	-2.00000E-03	-1.00000E+06	1.00000E+06
RQU	10		2.94000E-02	0.	0.
RAU	12		8.91000E-02	0.	0.
RRU	14		-6.44000E-02	0.	0.
XV	15	7	3.15000E-04	-1.00000E+06	1.00000E+06
YV	16	8	-7.06750E-02	-1.00000E+06	1.00000E+06
ZV	17	9	-5.32500E-03	-1.00000E+06	1.00000E+06
LV	18	10	-1.97500E-02	-1.00000E+06	1.00000E+06
MV	19	11	1.72500E-03	-1.00000E+06	1.00000E+06
NV	20	12	1.01250E-02	-1.00000E+06	1.00000E+06
RQV	24		5.00000E-04	0.	0.
RAV	26		-7.07000E-02	0.	0.
RRV	28		-5.06000E-02	0.	0.
XW	29	13	7.06500E-02	-1.00000E+06	1.00000E+06
YW	30	14	2.70000E-03	-1.00000E+06	1.00000E+06
ZW	31	15	-5.56000E-01	-1.00000E+06	1.00000E+06
LW	32	16	-1.23750E-02	-1.00000E+06	1.00000E+06
MW	33	17	1.20000E-03	-1.00000E+06	1.00000E+06
NW	34	18	-2.50000E-04	-1.00000E+06	1.00000E+06
RQW	38		4.32000E-01	0.	0.
RAW	40		3.79000E-02	0.	0.
RRW	42		-9.45000E-02	0.	0.
YP	43	19	-4.65000E-02	-1.00000E+06	1.00000E+06
YP-VSALF	44		6.63000E+00	0.	0.
ZP	45	20	-7.65000E+00	-1.00000E+06	1.00000E+06
LP	46	21	-1.29000E-01	-1.00000E+06	1.00000E+06
MP	47	22	-6.47500E-03	-1.00000E+06	1.00000E+06
NP	48	23	[illegible].22500E-02	-1.00000E+06	1.00000E+06
RAP	49		1.00000E+00	0.	0.
RQP	52		4.[illegible]E-01	0.	0.
RAW	54		-[illegible]	0.	0.
RRP	56		-1.[illegible]E+01	0.	0.
YQ-VSTH	57		-[illegible]	[illegible]	0.
YQ	[illegible]	[illegible]	-[illegible]E-01	-1.[illegible]	1.[illegible]

Figure 5.1 Sample Output

[illegible]	[illegible]	[illegible]	1.[illegible]	-1.00000E+06	1.00000E+06
PO	61	26	-6.25000E+00	-1.00000E+06	1.00000E+06
RO	62	27	6.65500E-02	-1.00000E+06	1.00000E+06
SPHOTTHI	63		0.	0.	0.
CPHO	64		1.00000E+00	0.	0.
EOQ	66		-3.97000E+00	0.	0.
HAO	68		-1.88000E+01	0.	0.
PQC	70		1.21000E+01	0.	0.
XS	71	28	1.08125E+00	-1.00000E+06	1.00000E+06
YS-YCALC	72		-1.67000E+02	0.	0.
ZS	73	29	3.36000E+00	-1.00000E+06	1.00000E+06
LS	74	30	5.53750E-01	-1.00000E+06	1.00000E+06
MS	75	31	3.37500E-03	-1.00000E+06	1.00000E+06
NS	76	32	-9.10000E-01	-1.00000E+06	1.00000E+06
CPHOTTHI	77		4.47000E-02	0.	0.
-SPHO	78		0.	0.	0.
EAQ	80		-3.06000E+00	0.	0.
QAR	82		1.56000E-01	0.	0.
PPQ	84		-7.20000E-01	0.	0.
GCPHOCTHO	86		3.22000E+01	0.	0.
-GSPHOCTHO	87		0.	0.	0.
-GCTHO	99		-3.22000E+01	0.	0.
-GSPHOSTHO	100		0.	0.	0.
-GCPHOSTHO	101		-1.44000E+00	0.	0.
XAO	113		2.51000E+01	0.	0.
YAO	114		-1.01000E+01	0.	0.
ZAO	115		-2.18000E+02	0.	0.
LAO	116		-5.20000E-01	0.	0.
MAO	117		-6.40000E-02	0.	0.
NAO	118		-1.40000E+00	0.	0.
PQAO	122	33	-1.26000E+02	-1.00000E+06	1.00000E+06
RAAO	124	34	1.11875E+02	-1.00000E+06	1.00000E+06
HHAO	126	35	-6.23250E+00	-1.00000E+06	1.00000E+06
XAODOT	127		4.16000E-02	0.	0.
YAODOT	128		-3.76000E-01	0.	0.
ZAODOT	129	36	9.98750E-01	-1.00000E+06	1.00000E+06
LAODOT	130		-1.00000E-02	0.	0.
MAODOT	131		-4.21000E-02	0.	0.
NAODOT	132		-1.52000E-02	0.	0.
ONE	135		1.00000E+00	0.	0.
PQAODOT	136	37	-1.02750E+01	-1.00000E+06	1.00000E+06
RSAODOT	138	38	4.15000E+00	-1.00000E+06	1.00000E+06
RHAODOT	140	39	1.17000E+00	-1.00000E+06	1.00000E+06
XA1	141		-2.40000E+01	0.	0.
YA1	142		4.32000E+00	0.	0.
ZA1	143		-1.11000E+01	0.	0.
LA1	144		-4.56000E+00	0.	0.
MA1	145		[illegible].64000E+00	0.	0.
NA1	146		-6.30000E-01	0.	0.
PQA1	150	40	2.37500E+01	-1.00000E+06	1.00000E+06
RAA1	152	41	-3.52500E+01	-1.00000E+06	1.00000E+06
HPA1	154	42	1.92500E+02	-1.00000E+06	1.00000E+06
XA1DOT	155		-2.51000E+00	0.	0.
YA1DOT	156		-2.10000E-01	0.	0.
ZA1DOT	157		3.76000E+00	0.	0.
LA1DOT	158		-4.72000E-01	0.	0.
MA1DOT	159	43	2.25000E-01	-1.00000E+06	1.00000E+06
NA1DOT	160		-6.32000E-02	0.	0.
PQA1DOT	164	44	1.24[illegible]75E+00	-1.00000E+06	1.00000E+06
ONE	165		1.00000E+00	0.	0.
RAA1DOT	166	45	-1.[illegible]E+01	-1.00000E+06	1.00000E+06
HPA1DOT	168	[illegible]	[illegible]E+01	-1.00000E+06	1.00000E+06
XB1	169		-1.[illegible]E+00	0.	0.
YB1	170		2.5[illegible]E+01	0.	0.
ZB1	171		1.17[illegible]E+01	0.	0.

Figure 5.1 (Continued)

[illegible]	[illegible]		1.[illegible]E+0[illegible]	0.	0.
NW1	174		1.84000E+00	0.	0.
ROR1	178	47	-1.26000E+01	-1.00000E+06	1.00000E+06
RAR1	180	48	-2.01250E+02	-1.00000E+06	1.00000E+06
RBR1	182	49	-3.[illegible]250E+01	-1.00000E+06	1.00000E+06
XR1DOT	183		-4.90000E-01	0.	0.
YR1DOT	184		9.23000E-01	0.	0.
ZR1DOT	185		-4.49000E+00	0.	0.
LR1DOT	186		1.07000E+00	0.	0.
MR1DOT	187		1.04000E-01	0.	0.
NR1DOT	188		8.00000E-02	0.	0.
ROR1DOT	192	50	-7.37500E-01	-1.00000E+06	1.00000E+06
RAR1DOT	194	51	-1.77750E+01	-1.00000E+06	1.00000E+06
ONE	195		1.00000E+00	0.	0.
RBR1DOT	196	52	-2.20000E+01	-1.00000E+06	1.00000E+06
XTHIS	197	53	-3.69000E+00	-1.00000E+06	1.00000E+06
YTHIS	198	54	1.50000E+01	-1.00000E+06	1.00000E+06
ZTHIS	199	55	9.30000E+01	-1.00000E+06	1.00000E+06
LTHIS	200	56	1.14125E+00	-1.00000E+06	1.00000E+06
MTHIS	201	57	-2.64000E-01	-1.00000E+06	1.00000E+06
NTHIS	202	58	-1.13125E-01	-1.00000E+06	1.00000E+06
ROTHIS	206	59	-4.815 00E+01	-1.00000E+06	1.00000E+06
RATHIS	208	60	-1.46250E+02	-1.00000E+06	1.00000E+06
RBTHIS	210		1.62000E+02	0.	0.
XTHIC	211		-4.92000E+00	0.	0.
YTHIC	212		1.19000E+01	0.	0.
ZTHIC	213		1.71000E+01	0.	0.
LTHIC	214		3.33000E+00	0.	0.
MTHIC	215		-7.95000E-02	0.	0.
NTHIC	216		-5.43000E-01	0.	0.
ROTHIC	220		9.82000E+00	0.	0.
RATHIC	222		1.63000E+02	0.	0.
RBTHIC	224		1.10000E+02	0.	0.
XDLTR	225		-4.80000E-01	0.	0.
YDLTR	226		6.67000E+00	0.	0.
ZDLTR	227		5.34000E-01	0.	0.
LDLTR	228		3.85000E+00	0.	0.
MDLTR	229		7.80000E-02	0.	0.
NDLTR	230		-5.17000E+00	0.	0.
RODLTR	234		-1.94000E+00	0.	0.
RADLTR	236		-5.30000E+01	0.	0.
RBDLTR	238		2.90000E-01	0.	0.
XTHO	239		2.65000E+01	0.	0.
YTHO	240		-7.08000E-01	0.	0.
ZTHO	241		-2.69000E+02	0.	0.
LTHO	242		-3.45000E+00	0.	0.
MTHO	243		6.60000E-01	0.	0.
NTHO	244		4.70000E+00	0.	0.
ROTHO	248		2.31000E+02	0.	0.
RATHO	250		3.07000E+01	0.	0.
RBTHO	252		-8.40000E+01	0.	0.
XU	253	1	-3.60000E-03	-1.00000E+06	1.00000E+06
YU	254	2	1.95000E-02	-1.00000E+06	1.00000E+06
ZU	255	3	-9.30000E-02	-1.00000E+06	1.00000E+06
LU	256	4	-1.37500E-03	-1.00000E+06	1.00000E+06
MU	257	5	-3.75000E-04	-1.00000E+06	1.00000E+06
NU	258	6	-2.00000E-03	-1.00000E+06	1.00000E+06
XV	267	7	3.15000E-04	-1.00000E+06	1.00000E+06
YV	268	8	-7.08750E-02	-1.00000E+06	1.00000E+06
ZV	269	9	[illegible]E-03	-1.00000E+06	1.00000E+06
LV	270	10	-1.[illegible]750[illegible]E-02	-1.00000E+06	1.00000E+06
MV	271	11	1.725[illegible]E-0[illegible]	-1.00000E+06	1.00000E+06
NV	272	12	[illegible]E-02	-1.00000E+06	1.00000E+06
XW	281	13	[illegible]E-02	-1.00000E+0[illegible]	1.00000E+0[illegible]
YW	282	14	[illegible]E-03	-1.[illegible]E+0[illegible]	1.[illegible]E+0[illegible]

Figure 5.1 (Continued)

L[illegible]	[illegible]	[illegible]	[illegible]	-1.[illegible]E+06	1.[illegible]
MA	[illegible]	17	1.20000E-03	-1.00000E+06	1.00000E+06
NA	[illegible]	18	-2.50000E-04	-1.00000E+06	1.00000E+06
XB	295	19	-4.45000E-02	-1.00000E+06	1.00000E+06
YB	296		-9.10000E-01	0.	0.
ZB	297	20	-7.65000E+00	-1.00000E+06	1.00000E+06
LB	298	21	-1.29000E-01	-1.00000E+06	1.00000E+06
MB	299	22	-6.87500E-0[illegible]	-1.00000E+06	1.00000E+06
NB	300	23	8.32500E-02	-1.00000E+06	1.00000E+06
ONE	301		1.00000E+00	0.	0.
XC	309		-2.42000E+00	0.	0.
YC	310	24	-4.23750E-01	-1.00000E+06	1.00000E+06
ZC	311		2.44000E+01	0.	0.
LC	312	25	1.27500E-02	-1.00000E+06	1.00000E+06
MC	313	26	-6.25000E+00	-1.00000E+06	1.00000E+06
NC	314	27	4.45500E-02	-1.00000E+06	1.00000E+06
ONE	316		1.00000E+00	0.	0.
XD	323	28	1.08125E+00	-1.00000E+06	1.00000E+06
YD	324		1.61000E+00	0.	0.
ZD	325	29	3.30000E+00	-1.00000E+06	1.00000E+06
LD	326	30	5.53750E-01	-1.00000E+06	1.00000E+06
MD	327	31	3.37500E-03	-1.00000E+06	1.00000E+06
ND	328	32	-9.10000E-01	-1.00000E+06	1.00000E+06
ONE	331		1.00000E+00	0.	0.
ONE	346		1.00000E+00	0.	0.
ONE	361		1.00000E+00	0.	0.
XA0	365		2.51000E+01	0.	0.
YA0	366		-1.01000E+01	0.	0.
ZA0	367		-2.19000E+02	0.	0.
LA0	368		-5.20000E-01	0.	0.
MA0	369		-6.40000E-02	0.	0.
NA0	370		-1.40000E+00	0.	0.
ONE	376		1.00000E+00	0.	0.
XA0DOT	379		4.16000E-02	0.	0.
YA0DOT	380		-3.76000E-01	0.	0.
ZA0DOT	381	36	9.96750E-01	-1.00000E+06	1.00000E+06
LA0DOT	382		-1.00000E-02	0.	0.
MA0DOT	383		-4.21000E-02	0.	0.
NA0DOT	384		-1.52000E-02	0.	0.
XA1	393		-2.40000E+01	0.	0.
YA1	394		4.32000E+00	0.	0.
ZA1	395		-1.11000E+01	0.	0.
LA1	396		-4.56000E+00	0.	0.
MA1	397		3.84000E+00	0.	0.
NA1	398		-8.30000E-01	0.	0.
ONE	405		1.00000E+00	0.	0.
XA1DOT	407		-2.51000E+00	0.	0.
YA1DOT	408		-2.10000E-01	0.	0.
ZA1DOT	409		3.78000E+00	0.	0.
LA1DOT	410		-4.72000E-01	0.	0.
MA1DOT	411	43	2.25000E-01	-1.00000E+06	1.00000E+06
NA1DOT	412		-5.32000E-02	0.	0.
XB1	421		-1.91000E+00	0.	0.
YB1	422		2.68000E+01	0.	0.
ZB1	423		1.17000E+01	0.	0.
LB1	424		1.78000E+01	0.	0.
MB1	425		1.00000E+00	0.	0.
NB1	426		1.84000E+00	0.	0.
ONE	434		1.00000E+00	0.	0.
XB1DOT	435		-4.90000E-01	0.	0.
YB1DOT	436		[illegible].23000E-01	0.	0.
ZB1DOT	437		-6.45000E+00	0.	0.
LB1DOT	438		1.07000E+00	0.	0.
MB1DOT	439		1.04000E-01	0.	0.
NB1DOT	440		[illegible]	0.	0.

Figure 5.1 (Continued)

Y[illegible]	[illegible]	[illegible]	1.[illegible]E+01	-1.[illegible]E+06	1.[illegible]E+06
ZTHIS	451	55	5.36000E+01	-1.00000E+06	1.00000E+06
LTHIS	452	56	1.14125E+00	-1.00000E+06	1.00000E+06
MTHIS	453	57	-2.64000E-01	-1.00000E+06	1.00000E+06
NTHIS	454	5[illegible]	-1.13125E-01	-1.00000E+06	1.00000E+06
XTHIC	463		-4.92000E+00	0.	0.
YTHIC	464		1.19000E+01	0.	0.
ZTHIC	465		1.71000E+01	0.	0.
LTHIC	466		3.33000E+00	0.	0.
MTHIC	467		-7.95000E-02	0.	0.
NTHIC	468		-5.43000E-01	0.	0.
XDLTR	477		-4.90000E-01	0.	0.
YDLTR	478		4.67000E+00	0.	0.
ZDLTR	479		5.34000E-01	0.	0.
LDLTR	480		3.85000E+00	0.	0.
MDLTR	481		7.80000E-03	0.	0.
NDLTR	482		-5.17000E+00	0.	0.
XTHO	491		2.65000E+01	0.	0.
YTHO	492		-7.08000E-01	0.	0.
ZTHO	493		-2.60000E+02	0.	0.
LTHO	494		-3.45000E+00	0.	0.
MTHO	495		6.60000E-01	0.	0.
NTHO	496		4.70000E+00	0.	0.
RAX	505		1.25000E-02	0.	0.
RAY	520		1.25000E-02	0.	0.
RAZ	535		1.25000E-02	0.	0.
RHDOT	550		1.53000E-05	0.	0.
RQDOT	565		1.53000E-05	0.	0.
RRDOT	580		1.53000E-05	0.	0.
RP	595		3.79000E-06	0.	0.
RQ	610		3.79000E-06	0.	0.
RR	625		3.79000E-06	0.	0.
RPHI	640		1.45000E-07	0.	0.
RTHETA	655		1.45000E-07	0.	0.
RA0	670		5.78000E-07	0.	0.
RA1	685		5.78000E-07	0.	0.
RB1	700		5.78000E-07	0.	0.

Figure 5.1 (Continued)

[illegible] [illegible]

***** SYSTEM MODEL WITH INITIAL VALUES OF PARAMETERS *****

F

	1	2	3	4	5	6	7	8	9	10
1	-3.6000E-03	3.1500E-04	7.0650E-02	-9.4500E-02	-9.9700E+00	1.0813E+06	0.	-3.2200E+01	2.5100E+01	4.1600E-02
2	1.9500E-02	-7.0875E-02	2.7000E-03	6.6300E+00	-8.2375E-01	-1.6700E+02	3.2200E+01	0.	-1.0100E+01	-3.7600E-01
3	-9.3000E-02	-5.3250E-03	-5.5100E-01	-7.6500E+00	1.9300E+02	3.3000E+00	0.	-1.4400E+00	-2.1800E+02	9.9875E-01
4	-1.3750E-02	-1.9750E-02	-1.2375E-02	-1.2900E-01	1.2750E-02	5.5375E-01	0.	0.	-5.2000E-01	-1.0080E-02
5	-3.7500E-04	1.7250E-03	1.2000E-03	-6.8750E-03	-6.2500E+00	3.3750E-03	0.	0.	-6.4000E-02	-4.2100E-02
6	-2.0000E-03	1.0125E-02	-2.6000E-04	8.3250E-02	4.4550E-02	-9.1000E-01	0.	0.	-1.4000E+00	-1.5200E-02
7	0.	0.	0.	1.0000E+00	0.	4.4700E-02	0.	0.	0.	0.
8	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.0000E+00
10	2.9400E-02	5.0000E-04	4.3200E-01	4.9500E-01	-3.9700E+00	-3.9600E+00	0.	0.	-1.2600E+02	-1.0275E+01
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	[illegible].9100E-02	-7.0700E-02	3.7900E-02	-8.4600E+00	-1.8800E+01	1.5600E-01	0.	0.	1.1188E+02	4.1500E+00
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	-[illegible].4400E-02	-5.0600E-02	-9.4500E-02	-1.5200E+01	1.2100E+01	-7.2000E-01	0.	0.	-6.2325E+00	1.1700E+00

F

	11	12	13	14
1	-2.4000E+01	-2.5100E+00	-1.9100E+00	-4.9000E-01
2	4.3200E+00	-2.1000E-01	2.5800E+01	9.2300E-01
3	-1.1100E+01	3.7600E+00	1.1700E+01	-4.4900E+00
4	-4.5600E+00	-4.7200E-01	1.7800E+01	1.0700E+00
5	3.8600E+00	2.2500E-01	1.0000E+00	1.0400E-01
6	-[illegible].3000E-01	-5.3200E-02	1.8400E+00	8.0000E-02
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	2.3750E+01	1.2498E+00	-1.2600E+01	-7.3750E-01
11	0.	1.0000E+00	0.	0.
12	-7.5250E+01	-1.4550E+01	-2.0125E+02	-1.7775E+01
13	0.	0.	0.	1.0000E+00
14	1.9250E+02	2.8500E+01	-3.6525E+01	-2.2000E+01

Figure 5.1 (Continued)

[illegible] [illegible]

G

	1	2	3	4
1	-3.6000E+00	-4.9200E+00	-4.4000E-01	2.6500E+01
2	1.5000E+01	1.1900E+01	5.5700E+00	-7.0800E-01
3	9.1000E+01	1.7100E+01	5.3400E-01	-2.6900E+02
4	1.1413E+00	3.3300E+00	3.8500E+00	-3.4500E+00
5	-2.6400E-01	-7.9500E-02	7.8000E-03	6.6000E-01
6	-1.1313E-01	-5.4300E-01	-5.1700E+00	4.7000E+00
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	-4.8150E+01	9.8230E+00	-1.9600E+00	2.3100E+02
11	0.	0.	0.	0.
12	-1.4625E+02	1.6300E+02	-5.3000E-01	3.0700E+01
13	0.	0.	0.	0.
14	1.6300E+02	1.1000E+02	2.9000E-01	-8.4000E+01

F

	1	2	3	4	5	6	7	8	9	10
1	-3.6000E-03	3.1500E-04	7.0650E-02	-9.4500E-02	-2.4200E+00	1.0813E+00	0.	0.	2.5100E+01	4.1600E-02
2	1.9500E-02	-7.0875E-02	2.7000E-03	-9.1000E-01	-8.2375E-01	1.6100E+00	0.	0.	-1.0100E+01	-3.7600E-01
3	-9.3000E-02	-5.3250E-03	-5.5800E-01	-7.6500E+00	2.4400E+01	3.3000E+00	0.	0.	-2.1800E+02	9.9875E-01
4	-1.3750E-03	-1.9750E-02	-1.2375E-02	-1.2900E-01	1.2750E-02	5.5375E-01	0.	0.	-5.2000E-01	-1.0000E-02
5	-3.7500E-04	1.7250E-03	1.2600E-03	-6.8750E-03	-6.2500E+00	3.3750E-03	0.	0.	-6.4000E-02	-4.2100E-02
6	-2.0000E-03	1.0125E-02	-2.5000E-04	8.3250E-02	4.4550E-02	-9.1000E-01	0.	0.	-1.4000E+00	-1.5200E-02
7	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	1.0000E+00	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	1.0000E+00	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	1.0000E+00	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 5.1 (Continued)

H

	11	12	13	14
1	-2.4000E+01	-2.5100E+00	-1.9100E+00	-4.9000E-01
2	4.3200E+00	-2.1900E-01	2.5900E+01	9.2300E-01
3	-1.1100E+01	3.7900E+00	1.1700E+01	-4.4900E+00
4	-4.5600E+00	-4.7200E-01	1.7900E+01	1.6700E+00
5	3.1400E+00	2.2500E-01	1.0000E+00	1.0400E-01
6	-8.3000E-01	-5.3200E-02	1.6600E+00	8.0000E-02
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	0.	0.	0.	0.
12	0.	0.	0.	0.
13	1.0000E+00	0.	0.	0.
14	0.	0.	1.0000E+00	0.

D

	1	2	3	4
1	-3.6900E+00	-4.9200E+00	-4.8000E-01	2.6500E+01
2	1.5000E+01	1.1900E+01	6.6700E+00	-7.0800E-01
3	5.3000E+01	1.7100E+01	5.3400E-01	-2.6900E+02
4	1.1413E+00	3.3300E+00	3.8500E+00	-3.4500E+00
5	-2.6400E-01	-7.9500E-02	7.8000E-03	6.6000E-01
6	-1.1113E-01	-5.4300E-01	-5.1700E+00	4.7000E+00
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	0.	0.	0.	0.
12	0.	0.	0.	0.
13	0.	0.	0.	0.
14	0.	0.	0.	0.

Figure 5.1 (Continued)

[illegible] [illegible]

P

	1	2	3	4	5	6	7	8	9	10
1	1.2500E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	1.2500E-02	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	1.2500E-02	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	1.5300E-05	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	1.5300E-05	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	1.5300E-05	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	3.7900E-06	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	3.7900E-06	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	3.7900E-06	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.4500E-07
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

P

	11	12	13	14
1	0.	0.	0.	0.
2	0.	0.	0.	0.
3	0.	0.	0.	0.
4	0.	0.	0.	0.
5	0.	0.	0.	0.
6	0.	0.	0.	0.
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	1.4500E-07	0.	0.	0.
12	0.	5.7800E-07	0.	0.
13	0.	0.	5.7800E-07	0.
14	0.	0.	0.	5.7800E-07

Figure 5.1 (Continued)

ITERATION NO. 8

GRADIENT

	1	2	3	4	5	6	7	8	9	10
1	9.7606E-01	-9.4560E+00	5.4065E+01	3.3027E+01	3.5678E+01	1.0180E+02	-8.9946E-02	3.7676E+01	-2.6467E+00	-3.6614E+02

GRADIENT

	11	12
1	-1.0191E+02	-5.4875E+02

INFORMATION MATRIX EIGENVALUES

	1	2	3	4	5	6	7	8	9	10
1	5.4067E+03	2.3083E+03	1.3395E+02	6.6271E+01	4.0124E+01	3.4480E+01	9.6173E+00	1.4236E+00	5.5158E-01	2.5698E-01

INFORMATION MATRIX EIGENVALUES

	11	12
1	1.5063E-01	2.1443E-03

			P	STD DEV OF P	F-VALUE
1	1	XU	-3.6000000E-03	7.2124934E-03	2.4913456E-01
2	2	YU	1.9500000E-02	8.6133216E-03	5.1254015E+00
3	3	ZU	-9.3000000E-02	1.7922754E-02	2.6925042E+01
4	4	LU	-1.3750000E-03	1.5949003E-03	7.4325580E-01
5	5	MU	-3.7500000E-04	3.7283064E-04	1.0116711E+00
6	6	NU	-2.0000000E-03	6.3844792E-04	9.8131637E+00
7	15	XV	3.1500000E-04	6.7991511E-03	2.1464053E-03
8	16	YV	-7.0875000E-02	6.3712063E-03	1.2374932E+02
9	17	ZV	-5.3250000E-03	1.4028697E-02	1.4408028E-01
10	18	LV	-1.9750000E-02	8.3300758E-04	5.6212940E+02
11	19	MV	1.7250000E-03	3.5882695E-04	2.3110433E+01
12	20	NV	1.0125000E-02	2.0898432E-04	2.3472679E+03
13	29	XW	7.0650000E-02		
14	30	YW	2.7000000E-03		
15	31	ZW	-5.5800000E-01		
16	32	LW	-1.2375000E-02		
17	33	MW	1.2000000E-03		
18	34	NW	-2.5600000E-04		
19	43	XP	-9.4500000E-02		
20	45	ZP	-7.6500000E+00		
21	46	LP	-1.2900000E-01		
22	47	MP	-6.8750000E-03		
23	48	NP	9.3250000E-02		
24	58	YQ	-4.2375000E-01		
25	60	LQ	1.2750000E-02		
26	61	MQ	-5.2600000E+00		
27	62	NQ	4.6500000E-02		
28	71	[illegible]	1.0312500E+00		

Figure 5.1 (Continued)

29	73	ZP	3.5100000E+00
30	74	LP	5.5475000E-01
31	75	MP	3.4750000E-03
32	76	NP	-4.1000000E-01
33	122	ROAP	-1.2650000E+02
34	124	RAAP	1.1187500E+02
35	126	RRAP	-5.2425000E+00
36	128	ZALDOT	9.5575000E-01
37	130	ROALDOT	-1.0275000E+01
38	136	RAZDOT	3.1550000E+00
40	150	ROA1	2.4750000E+01
41	152	RAA1	-3.6250000E+01
42	154	RRA1	1.0250000E+02
43	158	RA1DOT	2.2500000E-01
44	164	ROA1DOT	1.2487500E+00
45	166	RAA1DOT	-1.4550000E+01
46	168	RRA1DOT	2.0500000E+01
47	176	ROR1	-1.2600000E+01
48	180	RAR1	-2.0125000E+02
49	182	RRR1	-3.6525000E+01
50	192	ROR1DOT	-7.3750000E-01
51	194	RAR1DOT	-1.7775000E+01
52	196	RRR1DOT	-2.2000000E+01
53	197	XTHIS	-3.6900000E+00
54	198	YTHIS	1.5000000E+01
55	199	ZTHIS	9.3000000E+01
56	200	LTHIS	1.1412500E+00
57	201	MTHIS	-2.6400000E-01
58	202	NTHIS	-1.1312500E-01
59	206	ROTHIS	-4.8150000E+01
60	208	RATHIS	-1.4625000E+02

LIKELIHOOD FUNCTION = -2.3102572E+04

GRADIENT OF LIKE FUNCT = 7.2118250E+02

Figure 5.1 (Continued)

			NEW P	STEP	NORMALIZED STEP
1	1	XU	-3.9423561E-03	3.6234514E-04	1.0066420E-01
2	2	YU	3.9040232E-02	-1.9530232E-02	-1.0015504E+00
3	3	ZU	-1.0227564E-01	9.8755360E-03	1.0614356E-01
4	4	LU	2.2922784E-03	-3.6672784E-03	-2.6671115E+00
5	5	MU	-1.4551864E-03	1.0031864E-03	2.8846945E+00
6	6	NU	-3.9102955E-03	1.0142955E-03	9.5964776E-01
7	15	XV	3.2375840E-06	-8.7586026E-06	-2.7904452E-02
8	16	YV	-4.4468938E-02	1.4093934E-02	1.9885627E-01
9	17	ZV	-7.8940442E-03	2.5690442E-03	4.8244961E-01
10	18	LV	-1.8752441E-02	-9.0755890E-04	-5.0509311E-02
11	19	MV	9.9642511E-04	7.2617489E-04	4.2097095E-01
12	20	NV	1.0240699E-02	-1.1649923E-04	-1.1406344E-02
13	29	XW	7.0650000E-02		
14	30	YW	2.7000000E-03		
15	31	ZW	-5.5600000E-01		
16	32	LW	-1.2375000E-02		
17	33	MW	1.2000000E-03		
18	34	NW	-2.5000000E-04		
19	43	XP	-9.4500000E-02		
20	45	ZP	-7.6500000E+00		
21	46	LP	-1.2900000E-01		
22	47	MP	-6.8750000E-03		
23	48	NP	3.3250000E-02		
24	58	YQ	-8.2375000E-01		
25	60	LQ	1.2750000E-02		
26	61	MQ	-6.2500000E+00		
27	62	NQ	4.4550000E-02		
28	71	XR	1.0812500E+00		
29	73	ZR	3.3000000E+00		
30	74	LR	5.6375000E-01		
31	75	MR	3.3750000E-03		
32	76	NR	-4.1000000E-01		
33	122	RQAP	-1.2600000E+02		
34	124	RAAQ	1.1137500E+02		
35	126	RPAQ	-6.2325000E+00		
36	129	ZAQDOT	4.9875000E-01		
37	136	SQAQDOT	-1.0275000E+01		
38	138	PAAQDOT	4.1500000E+00		
39	140	RPAQDOT	1.1700000E+00		
40	150	RQA1	2.3750000E+01		
41	152	PAA1	-3.5250000E+01		
42	154	WQA1	1.9250000E+02		
43	159	MA1DOT	2.2500000E-01		
44	164	WQA1DOT	1.2487500E+00		
45	166	RAA1DOT	-1.4553000E+01		
46	168	WRA1DOT	2.9500000E+01		
47	179	RQF1	-1.2[illegible]00000E+01		
48	180	WAA1	-2.0125000E+02		
49	182	WPA1	-3.6625000E+01		
50	192	WQA1DOT	-7.3750000E-01		
51	194	WAA1DOT	-1.7775000E+01		
52	196	WPA1DOT	-2.2000000E+01		
53	197	XTHIS	-3.6000000E+00		
54	198	YTHIS	1.6000000E+01		
55	199	ZTHIS	9.3[illegible]00000E+01		
56	200	LTHIS	1.1612500E+00		
57	201	MTHIS	-2.6130000E-01		
58	202	NTHIS	-1.1312500E-01		
[illegible]	[illegible]	RQTHIS	-4.1150000E+01		
[illegible]	[illegible]	RATHIS	-1.2[illegible]E+02		

Figure 5.1 (Continued)

DI[illegible] (DISCRETE INNOVATIONS COVARIANCE)

	1	2	3	4	5	6	7	8	9	10
1	[illegible]	[illegible]	1.6561E+00	7.5384E-02	1.1796E-03	1.2150E-03	1.0524E-02	1.4144E-04	4.0577E-04	1.1303E-02

DIAGONAL ELEMENTS OF (DISCRETE INNOVATIONS COVARIANCE)

	11	12	13	14
1	[illegible]	2.4320E-05	5.0174E-05	2.1149E-04

Figure 5.1 (Continued)

			NEW P	STEP	NORMALIZED STEP
1	1	XH	3.2552079E-03	-4.0367329E-03	-5.3713893E+00
2	2	YH	2.0613995E-02	1.4204234E-02	4.1514267E-01
3	3	ZH	-8.9636113E-02	4.3019525E-04	5.3660156E-03
4	4	LH	2.0630524E-03	1.6576200E-03	4.4551524E-01
5	5	MH	-1.3030361E-03	-4.1941647E-04	-2.4349957E-01
6	6	NH	-2.8077777E-03	-6.6398301E-04	-1.9126253E-01
7	15	XV	-1.6056642E-03	2.0095498E-03	4.9755414E+00
8	16	YV	-6.8405547E-02	-8.4250312E-03	-1.2240245E-01
9	17	ZV	-5.1610946E-03	-1.1971273E-02	-6.5948825E-01
10	18	LV	-1.2079656E-02	-2.1569134E-04	-1.1790054E-02
11	19	MV	3.7293294E-03	-5.1060736E-04	-1.5863667E-01
12	20	NV	9.1035325E-03	-1.8618449E-05	-2.0491602E-03
13	29	XW	9.6494148E-02		
14	30	YW	4.5568971E-02		
15	31	ZW	-3.7320060E-01		
16	32	LW	1.6747808E-02		
17	33	MW	-6.6069084E-03		
18	34	NW	1.2251043E-03		
19	43	XP	-4.3699323E-01		
20	45	ZP	-4.2305727E+00		
21	46	LP	1.0420311E-01		
22	47	MP	5.6816067E-02		
23	48	NP	9.8616656E-02		
24	56	YQ	3.4991472E+00		
25	60	LQ	4.6943524E-01		
26	61	MQ	-5.4039809E+00		
27	62	NQ	-2.9677957E-02		
28	71	XR	1.4056125E+00		
29	73	ZR	1.0724126E+01		
30	74	LR	5.0313133E-01		
31	75	MR	-3.4864405E-02		
32	76	NR	-1.1891747E+00		
33	122	ROA0	-1.3814507E+02		
34	124	RAA0	4.2894305E+01		
35	126	RRA0	-7.1540269E+01		
36	129	ZA0DOT	-2.2922154E+00		
37	136	ROA0DOT	-9.5867032E+00		
38	138	RAA0DOT	5.6899013E+00		
39	140	RRA0DOT	-1.1980705E+00		
40	150	ROA1	2.4650369E+01		
41	152	RAA1	-5.1137205E+01		
42	154	RRA1	1.7513499E+02		
43	159	ZA1DOT	2.8231393E-01		
44	164	ROA1DOT	1.2401553E+00		
45	166	RAA1DOT	-2.0515757E+01		
46	168	RRA1DOT	2.7569202E+01		
47	178	ROB1	-1.6522556E+01		
48	180	RAB1	-1.7296061E+02		
49	182	RRB1	-2.9246466E+01		
50	192	ROB1DOT	-3.1701576E+00		
51	194	RAB1DOT	-1.[illegible]792E+01		
52	196	RRB1DOT	-2.2215225E+01		
53	197	XTHIS	-6.9210300E+00		
54	198	YTHIS	1.7517456E+01		
55	199	ZTHIS	1.0551230E+02		
56	200	LTHIS	1.6[illegible]E+00		
57	201	MTHIS	-4.51[illegible]1E-01		
58	202	NTHIS	-7.[illegible]13E-03		
59	204	[illegible]THIS	-4.[illegible]E+01		
60	206	[illegible]THIS	-1.[illegible]E+02		

Figure 5.1 (Continued)

DIAGONAL ELEMENTS OF R(DISCRETE INNOVATIONS COVARIANCE)

	1	2	3	4	5	6	7	8	9	10
1	[illegible]E-01	2.5576E-01	3.4589E-01	1.3225E-03	3.6790E-04	3.3587E-04	9.1730E-05	7.7392E-05	7.6846E-05	6.0934E-06

DIAGONAL ELEMENTS OF R(DISCRETE INNOVATIONS COVARIANCE)

	11	12	13	14
1	3.1819E-06	1.2176E-05	1.7880E-05	2.2903E-05

NUMBER OF ITERATIONS EXCEEDED

Figure 5.1 (Continued)

[illegible] [illegible] PROGRAM

***** SYSTEM MODEL WITH FINAL VALUES OF PARAMETERS *****

F

	1	2	3	4	5	6	7	8	9	10
1	-7.5152E-04	4.0309E-04	9.6494E-02	-4.3699E-01	-9.9700E+00	1.4056E+00	0.	-3.2200E+01	2.5100E+01	4.1600E-02
2	3.4223E-02	-6.6831E-02	4.5569E-02	6.6300E+00	3.4991E+00	-1.6700E+02	3.2200E+01	0.	-1.0100E+01	-3.7600E-01
3	-1.9156E-02	-1.6152E-02	-3.7320E-01	-4.2366E+00	1.9300E+02	1.0724E+01	0.	-1.4400E+00	-2.1800E+02	-2.2922E+00
4	9.7207E-03	-1.6294E-02	1.8709E-02	1.0420E-01	4.6944E-01	6.0313E-01	0.	0.	-5.2800E-01	-1.0000E-02
5	-1.7225E-03	3.2197E-03	-6.6069E-03	5.6816E-02	-5.4040E+00	-3.4268E-02	0.	0.	-6.4800E-02	-4.2100E-02
6	-5.4719E-03	9.0849E-03	1.2361E-03	9.8617E-02	-2.9578E-02	-1.1882E+00	0.	0.	-1.4000E+00	-1.5200E-02
7	0.	0.	0.	1.0000E+00	0.	4.4700E-02	0.	0.	0.	0.
8	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.0000E+00
10	2.9400E-02	5.0000E-04	4.3200E-01	4.9500E-01	-3.9700E+00	-3.9600E+00	0.	0.	-1.3815E+02	-9.5867E+00
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	1.9100E-02	-7.0700E-02	3.7900E-02	-8.4600E+00	-1.8800E+01	1.5600E-01	0.	0.	4.2804E+01	5.8900E+00
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	-6.4600E-02	-5.0600E-02	-9.4500E-02	-1.5209E+01	1.2100E+01	-7.2000E-01	0.	0.	-7.1540E+01	-1.1981E+00

F

	11	12	13	14
1	-2.4900E+01	-2.5100E+00	-1.9100E+00	-4.9000E-01
2	4.3200E+00	-2.1000E-01	2.5800E+01	9.2300E-01
3	-1.1109E+01	3.7800E+00	1.1700E+01	-4.4900E+00
4	-4.5500E+00	-4.7200E-01	1.7800E+01	1.0700E+00
5	9.5400E+00	2.6231E-01	1.0000E+00	1.0400E-01
6	-1.3000E-01	-5.3200E-02	1.8400E+00	8.0000E-02
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	2.4650E+01	1.2402E+00	-1.6523E+01	-3.1702E+00
11	0.	1.0000E+00	0.	0.
12	[illegible]	-2.0517E+01	-1.7284E+02	-1.9919E+01
13	0.	0.	0.	1.0000E+00
14	1.7513E+02	2.7549E+01	-2.9249E+01	-2.2216E+01

Figure 5.1 (Continued)

G

	1	2	3	4
1	-6.9210E+00	-4.9200E+00	-4.8000E-01	2.6500E+01
2	1.7517E+01	1.1900E+01	6.6700E+00	-7.0000E-01
3	1.0551E+02	1.7100E+01	5.3100E-01	-2.6900E+02
4	1.6634E+00	3.3300E+00	3.8500E+00	-3.4500E+00
5	-4.5064E-01	-7.9500E-02	7.4000E-03	6.6000E-01
6	-7.6445E-03	-5.4300E-01	-5.1700E+00	4.7000E+00
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	-4.6665E+01	9.8200E+00	-1.9400E+00	2.4100E+02
11	0.	0.	0.	0.
12	-1.4069E+02	1.6400E+02	-5.3000E-01	3.0700E+01
13	0.	0.	0.	0.
14	1.6300E+02	1.1000E+02	2.9000E-01	-6.4900E+01

H

	1	2	3	4	5	6	7	8	9	10
1	-7.5152E-04	4.0389E-04	9.6494E-02	-4.3699E-01	-2.4200E+00	1.4056E+00	0.	0.	2.5100E+01	4.1600E-02
2	2.6223E-02	-6.8831E-02	4.5569E-02	-9.1000E-01	3.4991E+00	1.6100E+00	0.	0.	-1.0100E+01	-3.7600E-01
3	-6.9156E-02	-1.8152E-02	-3.7320E-01	-4.2366E+00	2.4400E+01	1.0724E+01	0.	0.	-2.1800E+02	-2.2922E+00
4	3.7207E-03	-1.8294E-02	1.8788E-02	1.0420E-01	4.6944E-01	5.0313E-01	0.	0.	-5.2000E-01	-1.0000E-02
5	-1.7225E-03	3.2187E-03	-6.6069E-03	5.6816E-02	-5.4040E+00	-3.4866E-02	0.	0.	-6.4000E-02	-4.2100E-02
6	-3.4718E-03	9.0849E-03	1.2351E-03	9.8617E-02	-2.9678E-02	-1.1882E+00	0.	0.	-1.4000E+00	-1.5200E-02
7	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	1.0000E+00	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	1.0000E+00	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	1.0000E+00	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	1.0000E+00	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 5.1 (Continued)

B

	11	12	13	14
1	-2.4000E+01	-2.5100E+00	-1.9100E+00	-4.9000E-01
2	4.3200E+00	-2.1400E-01	2.5900E+01	9.2300E-01
3	-1.1100E+01	3.7000E+00	1.1700E+01	-4.4900E+00
4	-4.5600E+00	-4.7200E-01	1.7800E+01	1.0700E+00
5	3.5400E+00	2.8231E-01	1.0000E+00	1.0400E-01
6	-1.3000E-01	-5.3200E-02	1.8400E+00	8.0000E-02
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	0.	0.	0.	0.
12	0.	0.	0.	0.
13	1.0000E+00	0.	0.	0.
14	0.	0.	1.0000E+00	0.

D

	1	2	3	4
1	-7.9210E+00	-4.9200E+00	-4.8000E-01	2.6500E+01
2	1.7517E+01	1.1900E+01	6.6700E+00	-7.0800E-01
3	1.0551E+02	1.7100E+01	5.3400E-01	-2.6900E+02
4	1.6634E+00	3.3300E+00	3.8500E+00	-3.4500E+00
5	-4.5044E-01	-7.9500E-02	7.6000E-03	6.6000E-01
6	-7.5445E-03	-5.4300E-01	-5.1700E+00	4.7000E+00
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	0.	0.	0.	0.
12	0.	0.	0.	0.
13	0.	0.	0.	0.
14	0.	0.	0.	0.

Figure 5.1 (Continued)

C

	1	2	3	4	5	6	7	8	9	10
1	1.2500E-02	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	1.2500E-02	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	1.2500E-02	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	1.5300E-05	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	1.5300E-05	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	1.5300E-05	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	3.7900E-06	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	3.7900E-06	0.	0.
9	0.	0.	0.	0.	0.	0.	0.	0.	3.7900E-06	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.4500E-07
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

C

	11	12	13	14
1	0.	0.	0.	0.
2	0.	0.	0.	0.
3	0.	0.	0.	0.
4	0.	0.	0.	0.
5	0.	0.	0.	0.
6	0.	0.	0.	0.
7	0.	0.	0.	0.
8	0.	0.	0.	0.
9	0.	0.	0.	0.
10	0.	0.	0.	0.
11	1.4500E-07	0.	0.	0.
12	0.	5.7800E-07	0.	0.
13	0.	0.	5.7800E-07	0.
14	0.	0.	0.	5.7800E-07

***** PLOT FILE PRODUCED *****

Figure 5.1 (Continued)

Figure 5.1 (Continued)

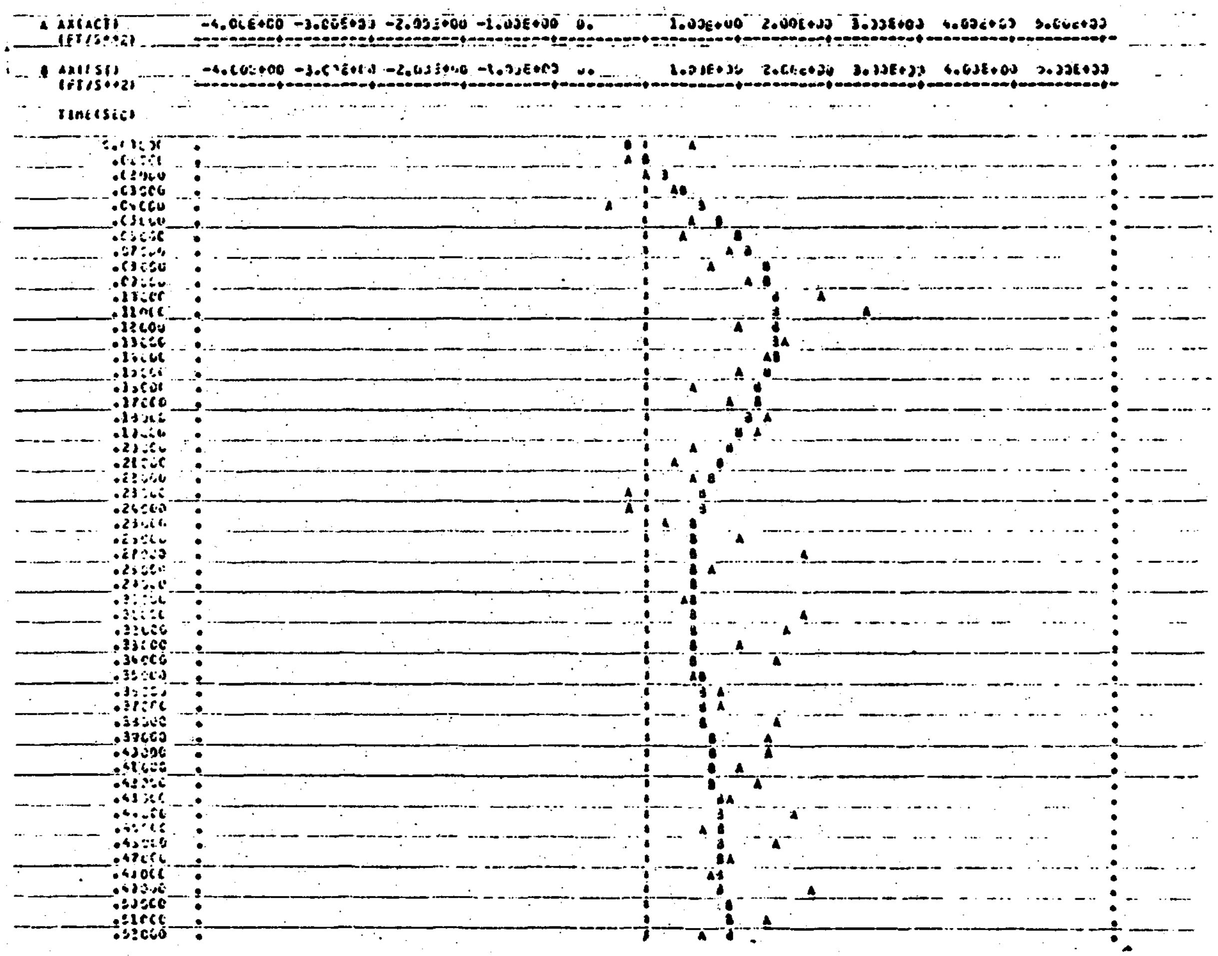

Figure 5.2 Measurement Time History

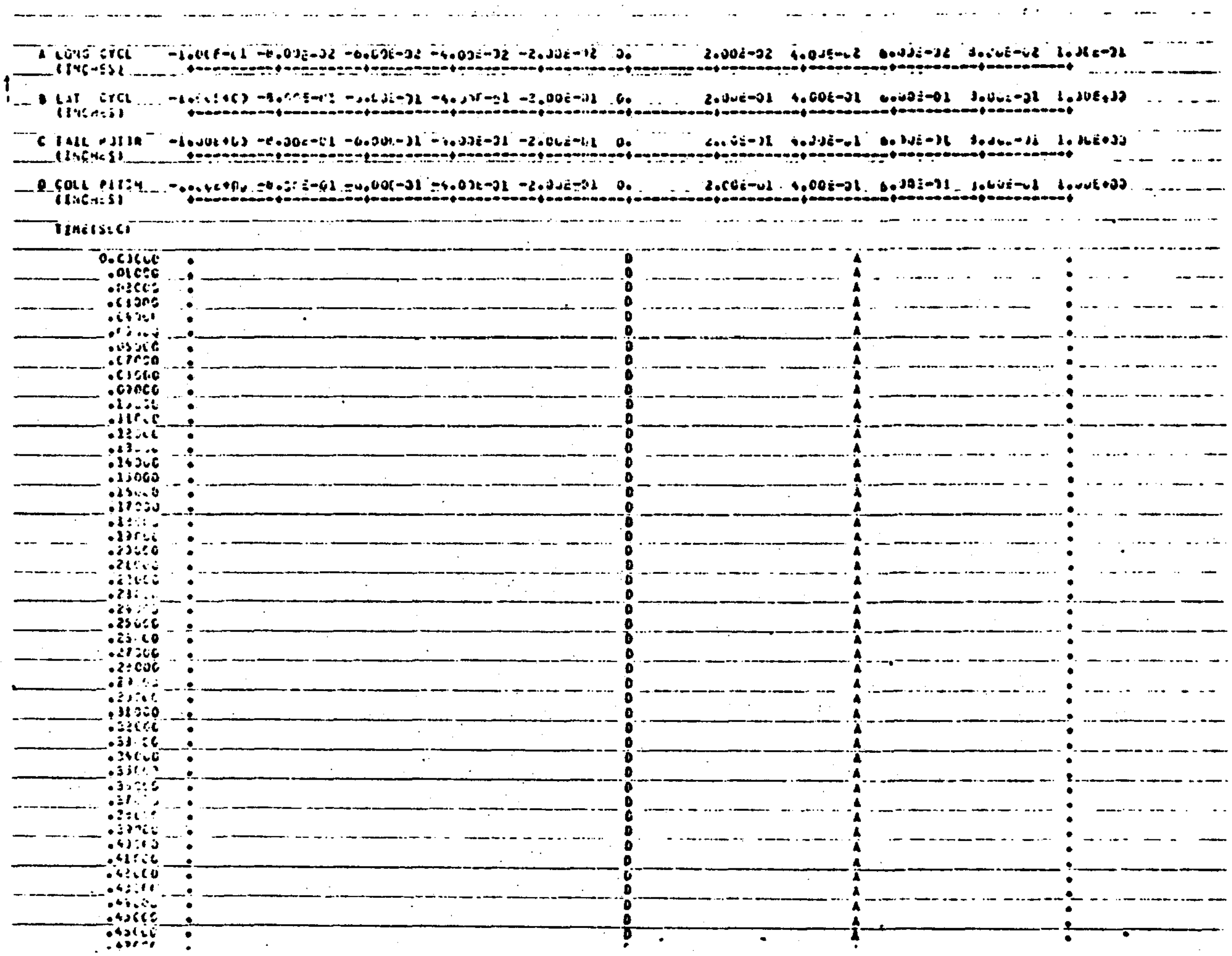

Figure 5.3 Control Time History

APPENDIX A

A.1 MAXIMUM PROBLEM DIMENSIONS

The Ames 7600 implementation of Linear SCIDNT is dimensioned to the following maximum problem sizes:

NS (number of states) $\leq$ 22

NQ (number of controls) $\leq$ 8

NP (number of measurements) $\leq$ 25

NG (number of process noise sources) $\leq$ 6

Total number of identified parameters $\leq$ 120

MCYCLE (number of parameters identified per iteration) $\leq$ 60

NN (number of data points) $\leq$ 1001

A.2 JOB CONTROL LANGUAGE REQUIRED TO USE LINEAR SCIDNT ON AMES 7600

The following job deck was used to make sample runs on simulated data. It can be used as an example for other SCIDNT job setups.

RCSCI,Tm,Pn,YD1. Job card. m and n depend on the particular run.

ACCOUNT,XXXXXX,TXXXX. Account card.

MOUNT,VSN=D0185A,FSDMOHA. Mount the private disk with the SCIDNT program and input data.

SETNAME,FSDMOHA. Establish the private disk as the default setname for subsequent ATTACHes.

ATTACH,RCCH53,ID=VERMONT. Attach the time history data file (card images in UPDATE format).

UPDATE,P=RCCH53,C=TAPE9,D,F. Un-compress the data file.

ATTACH,SCIDNT,LIDBN,ID=VERMONT. Attach the SCIDNT program.

SCIDNT. Load and execute SCIDNT.

7/8/9

This null logical record is needed for the UPDATE processor.

7/8/9

SCIDNT data cards (see Figure 4.1)

6/7/8/9